On the Causes and Predictability of Multi-Year North American Droughts with Applications to Drought Monitoring and Water Management

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Project hypothesis: 1) Global climate models together with NASA land-surface products can now provide us with fundamentally new insights into the causes and predictability of long-term drought over North America. 2) An applications effort that is strongly tied to the drought research community should be able to capitalize on our new understanding and predictive capabilities to substantially augment existing drought monitoring and water management capabilities.

Objectives & deliverables: 1) an improved understanding of the causes and predictability of long-term drought over North America, including the physical mechanisms that link past and future sea surface temperature changes to hydrological drought (seasonality, role of land surface feedbacks, signal to noise, predictability of onset versus demise), and 2) a demonstration of how NASA observations, together with our improved understanding and predictions can contribute to an early warning system for droughts, provide improved probabilistic drought recovery predictions, and improve water management decision support systems for selected river basins

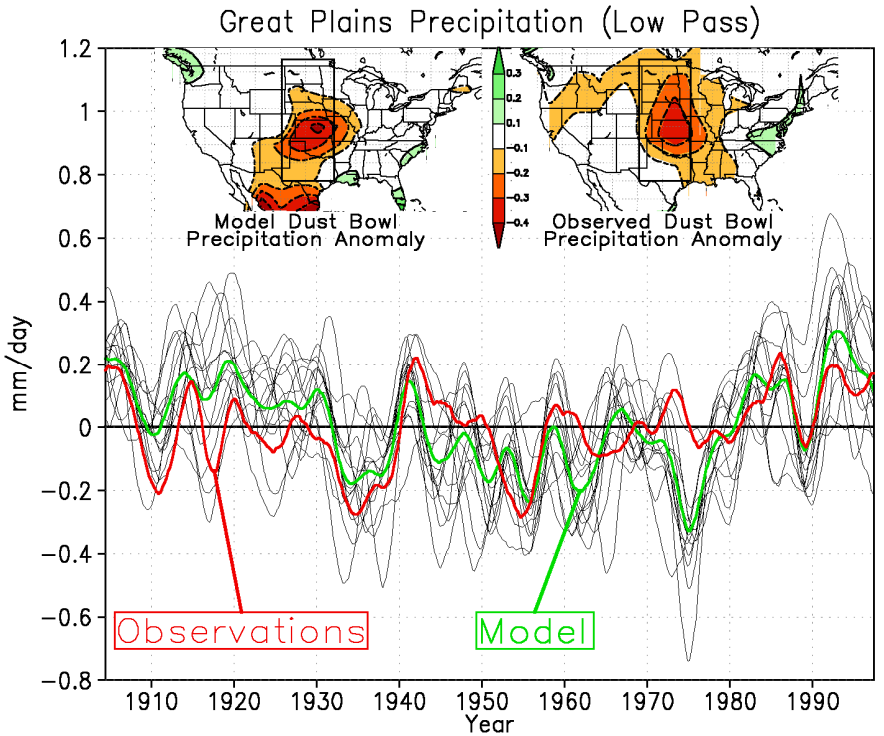
Technical approach and/or methods (NEWS Discovery):

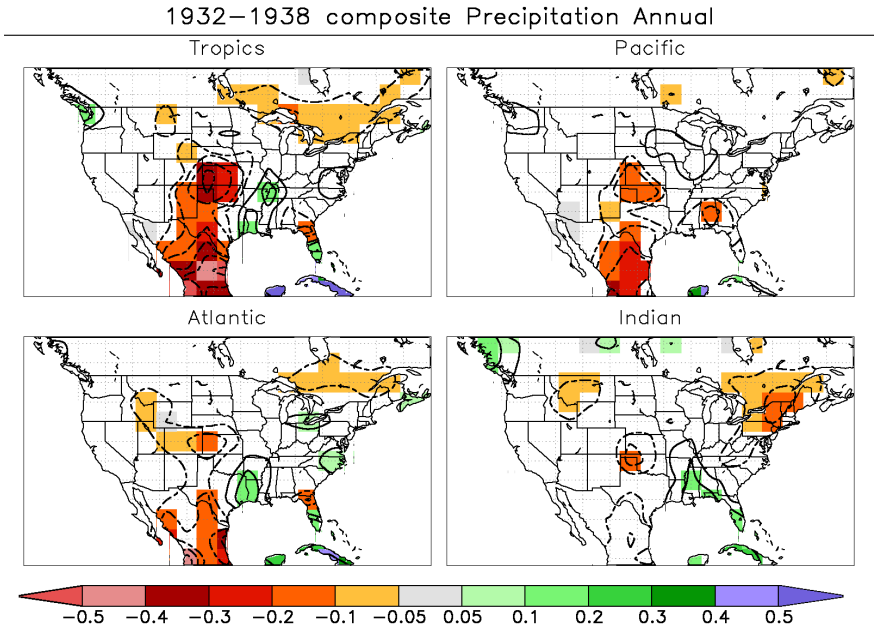
Part 1: Further evaluation of existing ensembles of NSIPP-1 AGCM runs forced with observed SSTs including an assessment of predictability, and mechanistic experiments designed to isolate the relevant SSTs, and to assess the impact of soil moisture feedbacks, and model resolution.

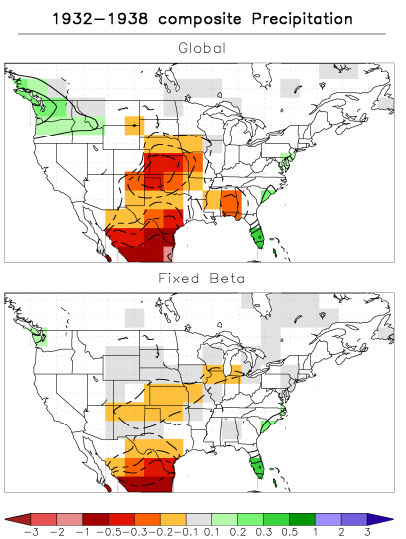
Part 2: Produce a new suite of long runs with the GEOS-5 AGCM. A key focus will be on droughts of the last several decades to allow a more direct utilization and comparison with reanalysis and other NASA observations. Focus will be on Pacific versus Atlantic Oceans and the seasonal cycle (role of land surface memory and feedbacks - snow pack, soil moisture; vegetation impacts; clarify the physical linkages between SST and hydrological drought, e.g., role of extreme weather events and low level jets)

Part 3: Carry out and analyze AGCM simulations forced with IPCC scenario SSTs to assess the potential impact of global warming on drought.

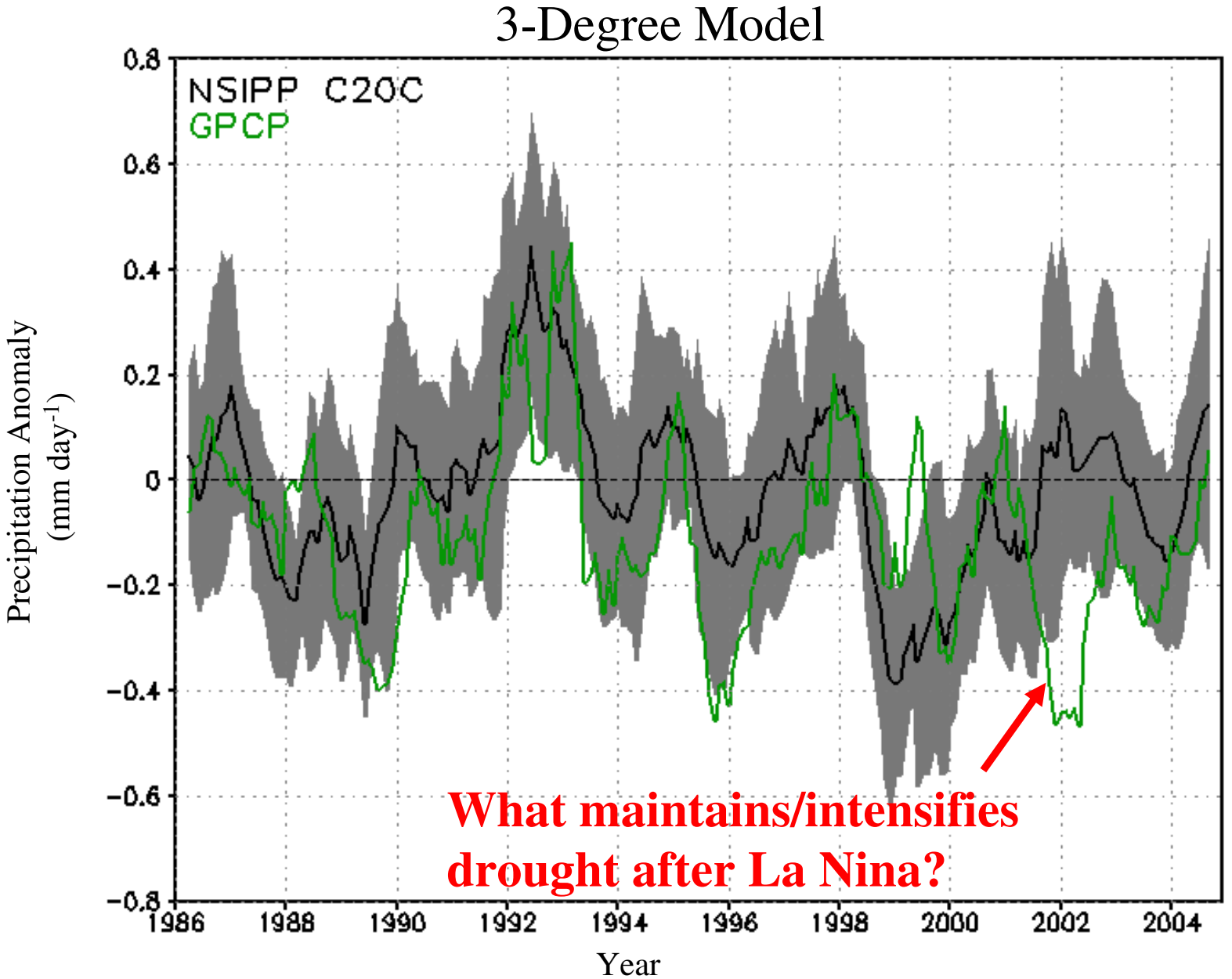
US Great Plains-Dust Bowl Drought







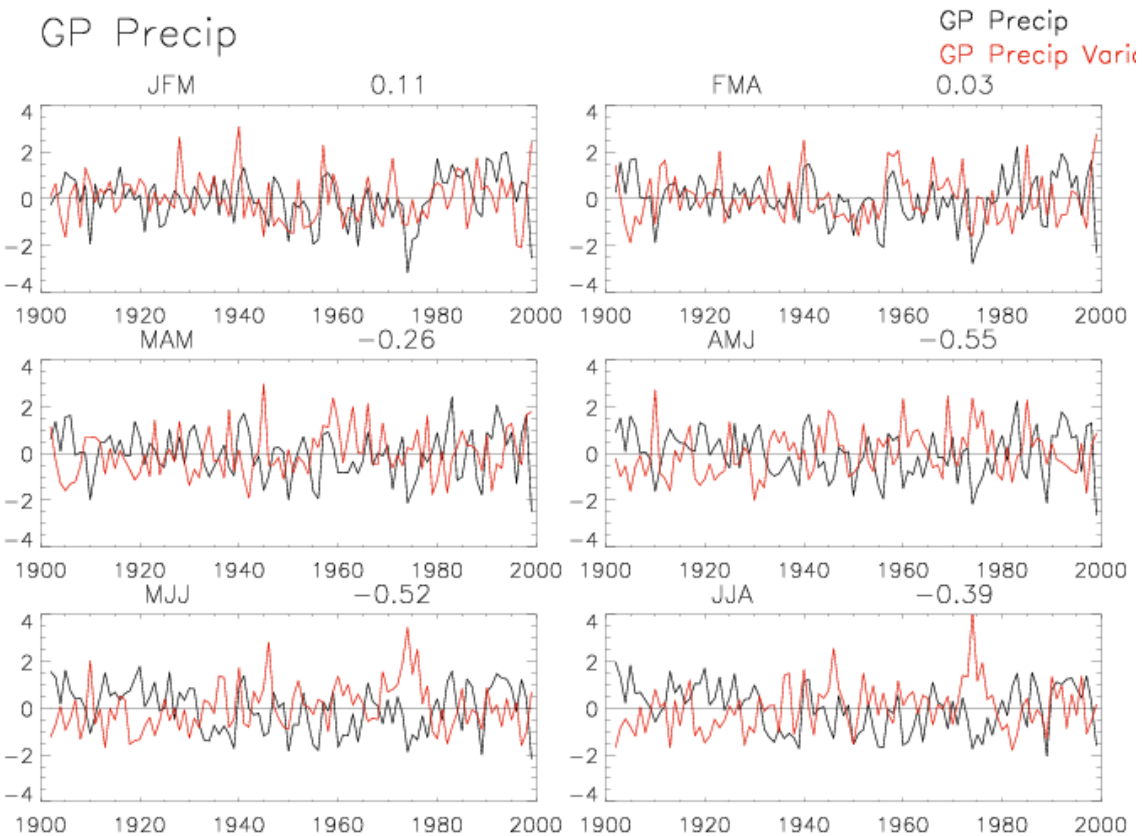
Desert Southwest



Does the predictability of precipitation change on inter-annual and longer time scales? Example - Great Plains.

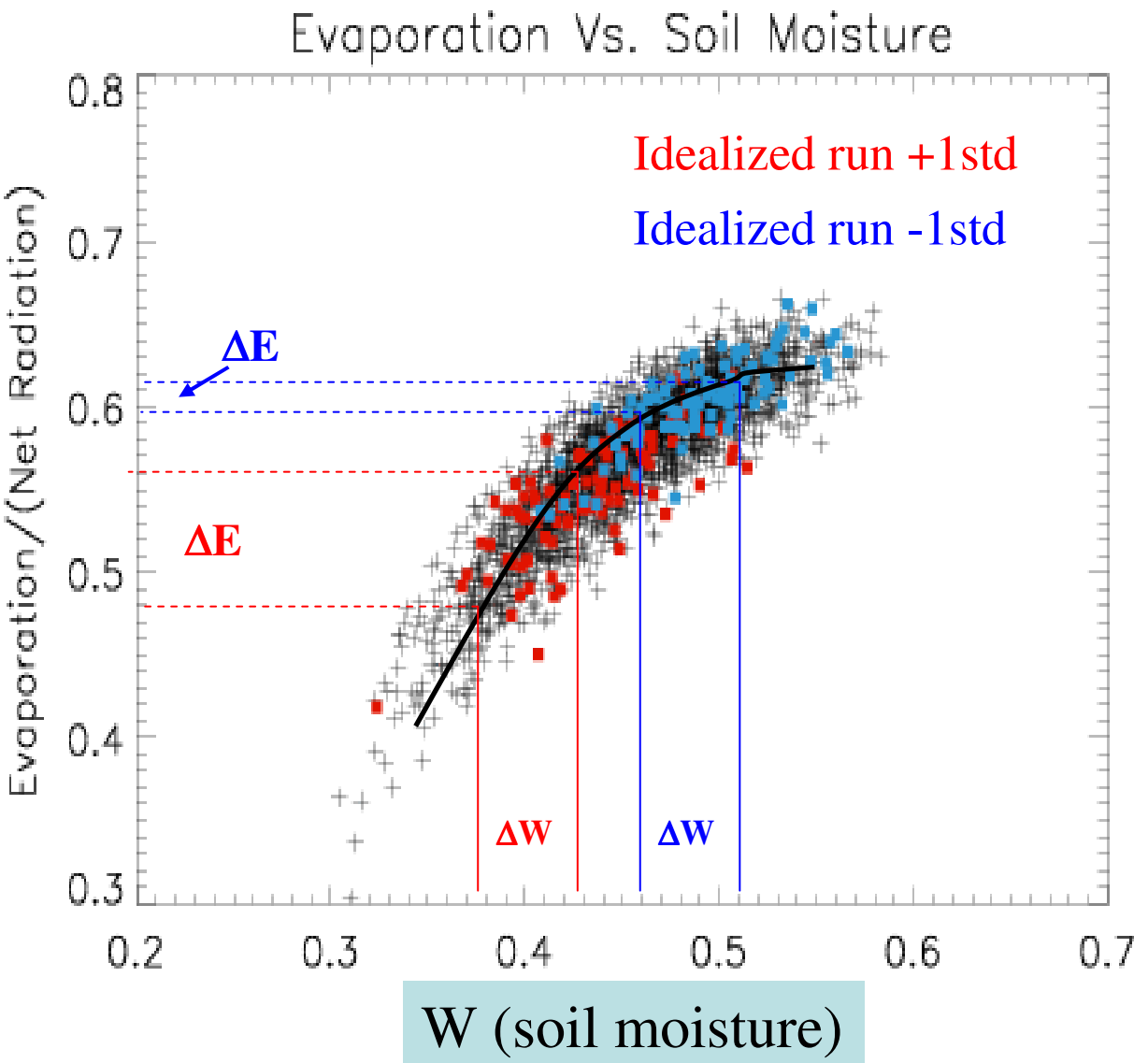
μ - ensemble mean

σ^2 - intra-ensemble variance



Why Are Droughts Less predictable than Wet Conditions?

Corr G.P. Precip (σ^2,μ)	
JFM	0.11
FMA	0.03
MAM	-.26
AMJ	-.55
MJJ	-.52
JJA	-.39
JAS	-.08
ASO	0.33
SON	0.54
OND	0.56
NDJ	0.41
DJF	0.19



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Surface Temperature and Precipitation Trends

Observed **Simulated**

Tsurf

Precip

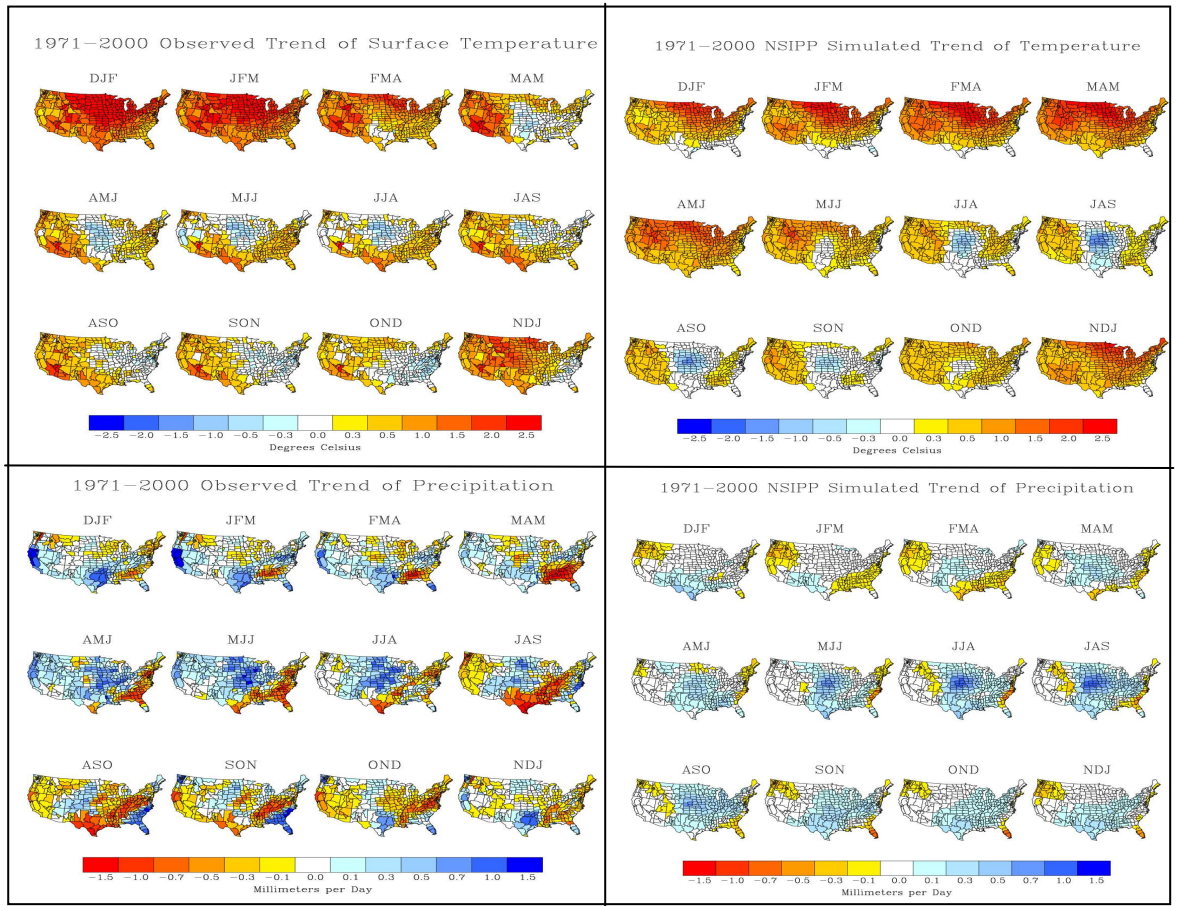

Figure 6: Observed (left panels) and simulated (right panels) trends for 1971-2000 for 3-month running means in surface temperature (top panels) and precipitation (lower panels). The simulated results are an ensemble mean of runs with the NSIPP-1 AGCM forced with observed SSTs (from Marty Hoerling, NOAA/CDC).

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Data set needs (particularly large data sets – include potential sizes)**:**

-GMAO, NCEP (global and regional) and ECMWF -atmospheric reanalyses
-Liu et al., Wentz et al. - oceanic evaporation and moisture transport
-Olson et al. - latent heating profiles
-Rodell/Reichle et al. land DAS products (soil moisture, snow)
-SST and vegetation from MODIS and AVHRR instruments.

Project outputs (project results that may be made available to the NEWS team for subsequent use – include potential size/resource requirements)**:**

-All AGCMS runs will be made available to the NEWS team and general community

Potential collaborations with NSIT, other NEWS projects, etc. :

Koster et al., Peters-Lidard et al. - land-atmosphere coupling strength
Olson et al. - heating profiles
Liu et al. Wentz et al. - oceanic evaporation and moisture transport
Bosilovich et al. - integration of existing, long-term global data sets, new NASA data sets, and global models to define modes of variability (inter-annual to decadal) in the global water and energy cycles.
Reichle et al. - 25-year retrospective global land surface data set by assimilating snow and soil moisture retrievals from SMMR, SSM/I, and AMSR-E. oil moisture
Rodell et al., - global snow water equivalent from Terra/Aqua MODIS snow cover and Aqua AMSR-E snow water equivalnt observations
Adler et al.,- 25+ year standard merged precipitation analyses (extension of GPCP, TRMM, Aqua/AMSR, etc.)

Important outside linkages/resources (outside the NEWS team) :

NOAA/OGP- (*Kumar, Hoerling and Schubert 2004: Advancing Best Practices in Seasonal Climate Predictions*). This proposal examines the skill of U.S. seasonal forecasts with a focus on attribution and determining the limit of SST-based predictability.

IPCC sub-project by Kumar et al., (2004) entitled "Attribution for 20th Century Regional Climate Trends. Here we will compare GEOS-5 climate of the 20th century IPCC runs with others from NCAR, GFDL (and possibly NCEP).

MERRA project (Bosliovich et al. 2003) - next generation reanalyses products (as they become available during year two) forr validating various aspects of atmospheric variability (e.g., moisture transports, weather variability).

Rienecker et al. 2004 MAP investigation to help assess the ability of the fully coupled (atmosphere-land-ocean) GMAO model to simulate realistic long-term droughts, and assess their predictability.

Drought Workshop (17-19 May 2005): Summary Report of the Workshop on: **Observational and Modeling Requirements for Predicting Drought on Seasonal to Decadal Time Scales (available soon)**

Important outside linkages/resources (collaborators) **:**

Don Wilhite – University of Nebraska, Director, National Drought Mitigation Center and International Drought Information Center: water management/drought mitigation community
Andrea Ray - NOAA/CDC: consult on water management for long-term drought
Doug Lecomte – NCEP/CPC: consult on drought monitoring, leads Drought Monitor activities

David Rind – NASA/GISS: coordinate IPCC SST runs and analysis of drought
Tom Delworth – GFDL: coordinate IPCC SST runs and analysis of drought
Phil Rasch – NCAR: coordinate IPCC SST runs and analysis of drought

Arun Kumar – NCEP/CPC: link to NOAA/CDEP proposal, also analysis of drought comparing results from NCEP model, IPCC subproject
Martin Hoerling - NOAA/CDC: analysis of drought comparing NCEP,NCAR, ECHAM3 models

Aiguo Dai – NCAR: drought work and the development of historical observational data sets for the analysis of the hydrological cycle
Bill Lau and Hailan Wang – NASA/GSFC: mixed layer ocean model experiments and climate variability.
Michael Bosilovich – NASA/GMAO: water vapor tracer simulations, MERRA reanalysis

Expected contribution to the NEWS objective:

NEWS-discovery: improved understanding of the causes (forcing) and predictability of multi-year North American droughts including an assessment of the potential impact of global warming.

WMP-discovery: improved drought monitoring capability, improved predictions of drought recovery, demonstration of the utility of model predictions for water management in various regions/river basins.

Issues, needs, and concern:

Long-term consistent data for model validation and initialization

- veracity of land-atmosphere feedbacks
- veracity of response to SST (signal-to-noise)
- long-term consistent model validation data (e.g., precipitation, evaporation, moisture transport)
- long-term consistent soil moisture (including deep soil moisture) and snow data for initialization